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CHARACTERISTICS OF RESIDUES IN A HELICOPTER LOGGED AREA OF OLD-GROWTH DOUGLAS-FIR

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ABSTRACT

The volume and character of residues in three old-growth Douglas-fir cutting units in the Oregon Cascades were determined before and after harvesting by helicopter and yarding of unutilized material (YUM). Two silvicultural treatments and two levels of YUM yarding were applied. Gross volumes of residues in all study units increased after logging. Yarding unutilized material appears to be effective in reducing the coarse residue and was more effective in the clearcut units than in the partial cut units. Study results indicate 65 to 80 percent of all residues generated had some potential for utilization. Specifications for yarding of unutilized material influenced the size and piece count distribution of the usable residue remaining on the study sites.

KEYWORDS: Residue surveys, slash utilization, helicopter logging, wood waste utilization.

Conversion factors are on page 33.

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INTRODUCTION

Residue information was obtained in studies conducted by the Pacific Northwest Forest and Range Experiment Station on three timber sale areas within the Pansy Creek drainage on the Estacada Ranger District of the Mt. Hood National Forest in Oregon. These sale areas were logged using balloon, helicopter, and skyline logging systems. The aim of the studies was to evaluate the performance of the systems in attaining land management objectives. The residues left after logging are an important factor to consider when evaluating the performance of a logging system.

Logging residues are a problem continually confronting land managers who are attempting to achieve the goals and objectives of multiple-use forestry. Land managers seek to manage logging residues to achieve optimum utilization of the resource, to minimize the risk of fire, and to achieve rapid regeneration in a manner that meets a wide range of environmental requirements. Information on the amounts and characteristics of residues generated by various logging systems is an important factor in decisions between alternative courses of action. This report, based on a case study, provides information on the quantities and characteristics of residues left in a helicopter logged area. The information presented can be used to evaluate the utilization potential of residues, fuel loadings, and the effects of changes in market conditions and contract requirements such as yarding of unutilized material (YUM).[1/]

The character and volume of residues left in a balloon logged area were reported in a previous paper (Pong and Henley 1976). A similar report on the skyline logged area is planned. Other published reports from this study effort deal with yarding rates and costs (Dykstra 1974, 1975, 1976a, 1976b, 1976c).

SCOPE AND PROCEDURE

Residues were inventoried on three 10- to 15-acre units of the helicopter logged sale. The study area was in steep and broken terrain with slopes varying from 10 to 90 percent. Old-growth Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco var. *menziesii*) and western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) were the principal species in the study area (about 83 percent by volume). Secondary species included western redcedar (*Thuja plicata* Donn) and true firs (*Abies* spp.).

Cruise volumes and the logging specifications of the units are given in table 1. The timber on units 2 and 3 was similar in that the gross cruise volumes were about 120,000 to 135,000 board feet per acre with an estimated defect of less than 10 percent. The timber on unit 1 contained less volume, about 75,000 board feet per acre, and had significantly more defect, about 38 percent. Units 1 and 2 were clearcut, and unit 3 was partial cut (86-percent volume removal).

[1/] In this report the acronym "YUM" will be used interchangeably to represent both the yarding process and the unutilized material that is yarded.

Table 1--*Cruised data and logging specifications for three study units Pansy Creek helicopter logging sale - Mt. Hood National Forest*

Study unit	Size (acres)	Cruised volumes[1/]				Percent defect	Cutting method	YUM[2/] specifications
		Gross	Net	Gross per acre	Net per acre			
1	10	749	463	75	46	38.2	clear-cut	12-inch d.i.b.[3/] or larger on large end, 10 feet long or longer
2	15	2,050	1,852	137	123	9.7	clear-cut	20-inch d.i.b. or larger on large end, 10 feet long or longer
3	13	1,532	1,429	118	110	6.7	partial-cut[4/]	20-inch d.i.b. or larger on large end, 10 feet long or longer

[1/] Thousand board feet Scribner.

[2/] Yarding of unutilized material.

[3/] Diameter inside bark.

[4/] Approximately 86 percent of merchantable volume removed.

Specifications in the timber sale contract required that all logs one-third sound with a minimum net scale of 80 board feet be removed. These specifications were applicable to 6-inch-d.i.b. (diameter inside bark) and larger logs at the small end, and to logs at least 8 feet long. The contract also required yarding of unutilized materials (YUM) as shown in table 1.

A planar intersect technique was used to inventory the downed woody residues on the units. The intersect technique involves tallying woody pieces that intersect imaginary vertical sampling planes dropped through the downed debris (Brown 1974, Van Wagner 1968). A systematic grid-point sampling design, with random orientation of a sampling plane at each point, was used to inventory each unit (Howard et al. 1972). At least 40 sample points were located in each unit. Pieces less than 3 inches in diameter were tallied by diameter classes and sampling plane lengths as follows:

0.25 to 0.99 inch	6 feet
1.0 to 2.99 inches	10 feet

Pieces 3 inches and larger were recorded by their diameters to the nearest inch. A 200-foot sampling plane was used for these larger pieces.

Particles qualifying for tally included downed woody material (twigs, stems, branches, and bolewood) from trees and shrubs. Dead branches attached to boles of standing trees were not tallied. Twigs and branches deposited in and above the litter layer were counted. Cones, bark flakes, needles, leaves, grass, and forbs were not counted. Slabs from shattered trees were recorded.

The size classes were chosen for tallying intersections because they permit precise estimates of volume and they correspond to the standard moisture timelags used in the National Fire-Danger Rating System (Deeming et al. 1972).

As each piece of residue 3 inches and greater in diameter (inside bark) was inventoried, the piece was classified according to its potential for utilization. Pieces less than 4 feet in length were not considered to be utilizable, and were classed as fuel. Pieces so decayed or splintered that they would not hold together if yarded were also classed as fuel. All others were placed in one of the following categories:

1. From a felled tree and bucked on at least one end.
2. From a felled tree and broken on both ends.
3. From prelogging (natural) residues, i.e., from dead and down windthrows, etc., and bucked on at least one end.
4. From prelogging residue and broken on both ends.

Information on species, length, and soundness was obtained for each piece considered to be usable. Length was recorded to the nearest foot. Soundness or percent firmwood (proportion of wood usable for pulp chips) was estimated to the nearest 10 percent at the point of

the sampling plane intersection. Estimates of soundness were based on the proportion of the cross-sectional area that was sound and judged as usable for pulp chips. Material decayed or excessively splintered was considered unusable and classed as fuel. The cross-sectional area at the sampling point was usually not visible. Thus, the soundness was estimated on the basis of surface and end characteristics of the piece and by a limited amount of sounding and chopping with hatchets.

These sampling procedures were used to inventory the natural residues present on the unit prior to any harvesting activities and also the residues that were left when the yarding operations were completed. The logging residues were sampled after the required yarding of unutilized material was complete, but prior to any further treatment of the remaining slash.

RESULTS

Harvesting Increased Total Residue Volume

The gross volume of all residues on the ground increased in all three study units following the harvesting operation (table 2). The largest increase occurred in unit 3 where residue volumes increased 44 percent (from 3,964 cubic feet to 5,715 cubic feet per acre), followed by unit 2 with a 25-percent increase (3,749 cubic feet to 4,678 cubic feet), and unit 1 with a 18-percent increase (from 4,528 cubic feet to 5,355 cubic feet). The volumes of residue before and after the logging operation in various diameter classes on each of the three study units are presented in table 3.

YUM Yarding Reduced Coarse Residues

Not all diameter classes of residues increased in volume after logging. In units 1 and 2, volume increases generally were limited to the fuels, smaller size coarse residues (3-13 inches), and residues in the 31.5-34.4-inch diameter class and slabs; decreases were recorded in all other residue sizes. In unit 3, nearly every diameter class of residue increased in volume following logging. In only one diameter class (19.5-22.4 inches) was there a noticeable decrease.

YUM yarding appeared to be effective in reducing the coarse logging residues in the study units. The gross volume of YUM material removed from unit 1, for example, averaged 2,433 cubic feet per acre. This was comparable to the 5,355 cubic feet per acre of logging residue left on the ground. We can assume that most if not all of the YUM volume was in pieces meeting the 12-inch YUM specifications for unit 1 (table 1). Though comparable figures for the YUM removed from units 2 and 3 are not available, results from unit 1 strongly suggest that YUM yarding did reduce the potential volume of coarse logging residues in the study units.

The fact that in units 1 and 2 there was a decrease in the coarse residue volume for many diameter classes following the logging operation indicates that removal of some of the prelogging residue had taken place

Table 2--*Average gross volumes of usable and unusable residues, piece count of usable residues before and after logging, and gross volumes of YUM[1] and merchantable logs removed from three study units, Pansy Creek helicopter sale - Mt. Hood National Forest*[2]

Study unit	Residue			Usable residue	YUM	YUM plus usable residue	Merchantable log volume removed
	Usable	Unusable	Total				
	- - -Cubic feet per acre- - -			Pieces per acre	- - - - - -Cubic feet per acre- - - - - -		
Unit 1:							
Before logging	1,606	2,922	4,528	61	2,433	5,031	6,387
After logging	2,598	2,757	5,355	816			
Unit 2:							
Before logging	1,873	1,876	3,749	94	[3]2,941	6,081	13,477
After logging	3,140	1,538	4,678	1,020			
Unit 3:							
Before logging	1,714	2,250	3,964	129	[3]3,667	7,583	9,598
After logging	3,916	1,799	5,715	1,226			

[1] Yarding of unutilized material (removed during logging operation).

[2] Information in this table is summarized from data presented in other tables in this report.

[3] Estimated from proportions in unit 1.

Table 3--*Average gross volume of residues before and after logging, by diameter class for three study units, Pansy Creek helicopter logging sale - Mt. Hood National Forest*

Diameter class (inches)	Unit 1		Unit 2		Unit 3	
	Before logging[1/]	After logging[2/]	Before logging[1/]	After logging[2/]	Before logging[1/]	After logging[2/]
	-Cubic feet per acre-					
0.26- 1.0	141.9	133.8	94.6	159.9	165.8	171.2
1.1 - 2.9	205.4	334.1	179.1	479.3	215.9	568.8
3.0 - 4.4	93.4	309.2	46.0	325.7	143.8	251.3
4.5 - 7.4	73.2	342.9	50.9	581.7	206.5	598.1
7.5 - 10.4	233.6	291.2	263.7	585.8	735.3	982.6
10.5 - 13.4	347.2	343.4	442.3	521.0	618.0	901.0
13.5 - 16.4	316.6	288.3	552.0	517.0	750.7	729.4
16.5 - 19.4	309.0	267.1	377.9	316.3	551.0	572.1
19.5 - 22.4	308.4	257.7	455.7	323.9	507.7	196.3
22.5 - 25.4	325.9	249.0	268.7	262.3	26.9	186.1
25.5 - 28.4	290.7	257.3	382.2	131.1	0	214.3
28.5 - 31.4	440.8	361.1	335.9	39.2	42.0	44.8
31.5 - 34.4	47.8	143.8	0	53.9	0	50.8
34.5+	1,387.7	565.6	298.6	57.1	0	0
Slabs	6.8	1,210.9	1.4	323.8	0	248.3
Total	4,528.3	5,355.4	3,748.8	4,678.1	3,963.6	5,715.0

[1/] Dead and down material which includes material not yardable, less than 10 percent sound, and less than 3 inches in diameter and 4 feet long.

[2/] All down material which includes material not yardable, less than 10 percent sound, and less than 3 inches in diameter and 4 feet long.

during the harvesting operation. YUM yarding probably accounted for much of this reduction. Some reduction may also have resulted from the utilization of the sounder pieces of prelogging residue; this was especially true in the larger diameter material.

Even with YUM yarding, residue volumes remaining on unit 3 for most diameter classes were greater than those recorded during the prelogging inventory (table 3). This suggests that YUM yarding in unit 3 (a partial cut) was less effective in reducing coarse residues than in units 1 and 2 (clearcuts).

The gross volume of merchantable logs removed from unit 1 during the helicopter logging operation, as tallied at the truck scale station, was 6,387 cubic feet per acre. This was comparable to the gross residue volume left on the ground of 5,355 cubic feet and a total unused wood volume (logging residue plus YUM) of 7,788 cubic feet. Comparable figures for units 2 and 3 were not recorded.

Utilization Potential of Residues

The portion of the total residue volume that has some potential for utilization is defined as material which can be yarded without breaking up and is at least 10 percent sound, 3 inches and greater in diameter, and at least 4 feet long. According to these specifications, on unit 1, 1,606 cubic feet per acre--about 35 percent of the prelogging residue (coefficient of variation of 90.2 percent), on unit 2, 1,873 cubic feet per acre--about 50 percent (coefficient of variation of 91.0 percent), and on unit 3, 1,714 cubic feet per acre--about 43 percent (coefficient of variation of 67.8 percent) could be utilized. A breakdown of these volumes by diameter and length classes for each unit are contained in tables 4, 5, and 6. Some of the larger and sounder natural residues were probably salvaged during the harvesting operation; the remainder was either removed as YUM or left on the site. Volumes of usable and unusable prelogging residues for each unit are graphically presented in figure 1 and summarized in table 2.

Much of the prelogging residue was defective. The average soundness of the usable prelogging residues was 63 percent for unit 1, 72 percent for unit 2, and 65 percent for unit 3. Comparable figures for the logging residues were higher, averaging 65 percent for unit 1 and 81 percent for units 2 and 3. Removal of the larger and sounder prelogging residues during the logging operation reduced, to some extent, the average soundness of the remaining residues. The yarding of the unutilized material, however, tends to increase the average soundness of the residue left on the logging site. This is especially true if some of the material removed as YUM did not have the potential for utilization according to our study specifications. A decrease in unusable residue volume on each of the study units (table 2) after logging and YUM yarding indicates that some removal of this type material had occurred. The species composition and soundness data of the usable residues before and after the harvesting operation on each study unit are presented in tables 7-12.

Table 4--*Average gross and net volumes of usable prelogging residue by diameter and length classes, Study Unit 1, Pansy Creek helicopter logging sale*[1]*/-Mt. Hood National Forest*

Diameter class (inches)	Volume of all classes		Length class (feet)							
			4.0-7.9		8.0-13.9		14.0-20.9		21.0+	
	Gross	Net	Gross	Net	Gross	Net	Gross	Net	Gross	Net
	-Cubic feet per acre-									
3.0 - 4.4	12.4	10.4	5.2	4.6	4.2	3.6	1.7	1.2	1.3	1.0
4.5 - 7.4	11.2	9.1	2.9	1.3	4.5	4.1	2.6	2.6	1.2	1.2
7.5 - 10.4	41.4	35.7	2.3	.5	9.8	9.0	8.3	8.2	21.0	18.1
10.5 - 13.4	53.7	24.5	6.7	3.0	16.8	4.0	3.4	1.3	26.9	16.1
13.5 - 16.4	90.3	53.1	0	0	31.6	17.0	9.1	5.5	49.5	30.6
16.5 - 19.4	67.2	46.9	0	0	22.7	18.1	0	0	44.5	28.7
19.5 - 22.4	76.6	38.4	9.3	1.9	0	0	9.3	2.8	57.9	33.8
22.5 - 25.4	218.4	122.4	14.6	0	26.9	6.7	26.9	9.4	150.1	106.3
25.5 - 28.4	227.6	132.8	0	0	18.3	11.0	65.6	27.7	143.8	94.1
28.5 - 31.4	188.9	128.1	0	0	0	0	21.0	12.6	167.9	115.5
31.5 - 34.4	47.8	26.3	0	0	0	0	23.9	4.8	23.9	21.5
34.5+	563.3	383.2	0	0	0	0	0	0	563.3	383.2
Slabs	6.8	4.6	1.1	1.1	2.1	2.1	3.6	1.4	0	0
Total	1,605.7	1,015.5	42.1	12.4	137.0	75.7	175.3	77.5	1,251.3	850.0

[1]/ Includes all dead and down material averaging at least 3.0 inches in diameter (inside bark) and 4.0 feet long, at least 10 percent sound, and yardable.

Table 5--*Average gross and net volumes of usable prelogging residue by diameter and length classes, Study Unit 2, Pansy Creek helicopter logging sale*[1/] *- Mt. Hood National Forest*

Diameter class (inches)	Volume of all classes		Length class (feet)							
			4.0-7.9		8.0-13.9		14.0-20.9		21.0+	
	Gross	Net	Gross	Net	Gross	Net	Gross	Net	Gross	Net
	- - -

Table 6--*Average gross and net volumes of usable prelogging residue by diameter and length classes, Study Unit 3, Pansy Creek helicopter logging sale*[1]*- Mt. Hood National Forest*

Diameter class (inches)	Volume of all classes		Length class (feet)							
			4.0-7.9		8.0-13.9		14.0-20.9		21.0+	
	Gross	Net	Gross	Net	Gross	Net	Gross	Net	Gross	Net
	Cubic feet per acre									
3.0 - 4.4	4.8	2.9	0	0	1.2	.3	1.3	.9	2.3	1.7
4.5 - 7.4	39.0	30.3	5.7	3.2	1.2	.2	14.7	12.7	17.4	14.2
7.5 - 10.4	305.2	210.6	31.0	20.3	49.7	32.0	73.4	50.8	151.1	107.5
10.5 - 13.4	268.7	165.9	26.9	17.5	53.7	24.2	67.2	39.6	120.9	84.6
13.5 - 16.4	441.5	231.5	45.7	9.6	66.8	34.4	84.3	45.8	244.6	141.8
16.5 - 19.4	302.3	192.0	0	0	45.3	10.6	45.3	22.7	211.6	158.7
19.5 - 22.4	283.8	221.8	0	0	56.0	37.3	37.3	31.7	190.5	152.8
22.5 - 25.4	26.9	24.2	0	0	0	0	0	0	26.9	24.2
25.5 - 28.4	0	0	0	0	0	0	0	0	0	0
28.5 - 31.4	42.0	33.6	0	0	0	0	0	0	42.0	33.6
31.5 - 34.4	0	0	0	0	0	0	0	0	0	0
34.5+	0	0	0	0	0	0	0	0	0	0
Slabs	0	0	0	0	0	0	0	0	0	0
Total	1,714.0	1,112.8	109.3	50.5	273.9	139.0	323.6	204.1	1,007.3	719.1

[1] Includes all dead and down material averaging at least 3.0 inches in diameter (inside bark) and 4.0 feet long, at least 10 percent sound, and yardable.

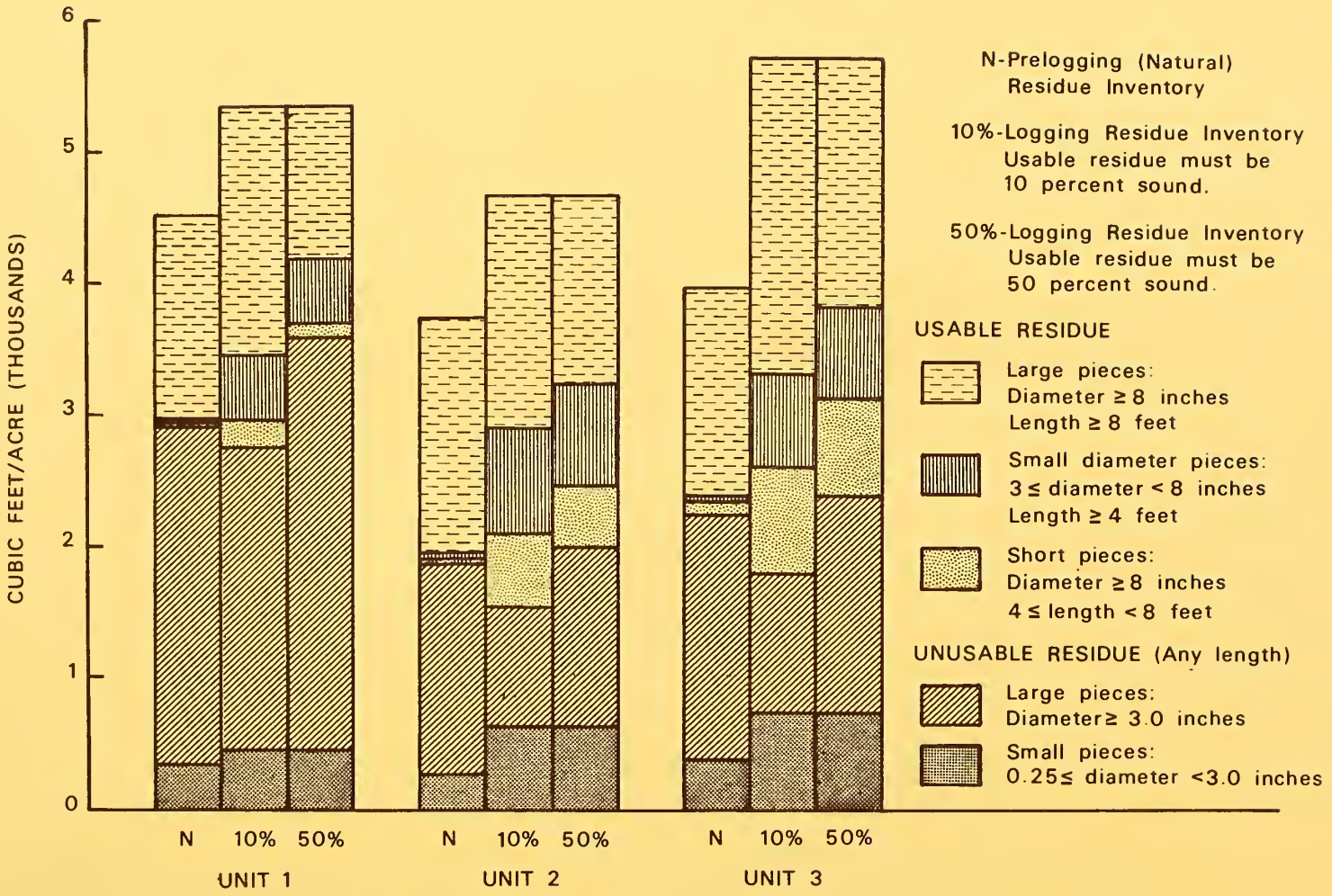
CUBIC FEET/ACRE (THOUSANDS)
6
5
4
3
2
1
0
N 10% 50%
UNIT 1
N 10% 50%
UNIT 2
N 10% 50%
UNIT 3
N-Prelogging (Natural) Residue Inventory
10%-Logging Residue Inventory Usable residue must be 10 percent sound.
50%-Logging Residue Inventory Usable residue must be 50 percent sound.
USABLE RESIDUE
Large pieces: Diameter ≥ 8 inches Length ≥ 8 feet
Small diameter pieces: 3 ≤ diameter < 8 inches Length ≥ 4 feet
Short pieces: Diameter ≥ 8 inches 4 ≤ length < 8 feet
UNUSABLE RESIDUE (Any length)
Large pieces: Diameter ≥ 3.0 inches
Small pieces: 0.25 ≤ diameter < 3.0 inches

Figure 1.--Average gross volume of usable and unusable prelogging and logging residues grouped by soundness and size for three helicopter study units--Pansy Creek helicopter logging sale, Mt. Hood National Forest.

Table 7--*Average gross and net volumes of usable prelogging residue by species, Study Unit* 1, *Pansy Creek helicopter logging sale*[1/] *- Mt. Hood National Forest*

Species	Gross volume	Net volume	Soundness	Proportion of total
	- - -Cubic feet per acre- - -		- - -Percent- - -	
Douglas-fir	38.8	26.9	69.3	2.4
Hemlock	1,041.5	592.9	56.9	64.9
Cedar	459.8	331.9	72.2	28.6
Pines	13.4	13.4	100.0	.8
Other softwoods	52.0	50.3	96.8	3.2
Hardwoods	0	0	0	0
Total	1,605.7	1,015.5	63.2	[2/]99.9

[1/] Includes all dead and down material averaging at least 3.0 inches in diameter (inside bark) and 4.0 feet long, at least 10 percent sound, and yardable.

[2/] Total does not equal 100 because of rounding.

Table 8--*Average gross and net volumes of usable prelogging residue by species, Study Unit 2, Pansy Creek helicopter logging sale*[1/] *- Mt. Hood National Forest*

Species	Gross volume	Net volume	Soundness	Proportion of total
	- - -Cubic feet per acre- - -		- - -Percent- - -	
Douglas-fir	1,291.7	852.1	66.0	69.0
Hemlock	238.0	162.5	68.3	12.7
Cedar	0	0	0	0
Pines	333.8	321.3	96.2	17.8
Other softwoods	9.1	9.1	100.0	.5
Hardwoods	0	0	0	0
Total	1,872.6	1,345.0	71.8	100.0

[1/] Includes all dead and down material averaging at least 3.0 inches in diameter (inside bark) and 4.0 feet long, at least 10 percent sound, and yardable.

Table 9--*Average gross and net volumes of usable prelogging residue by species, Study Unit 3, Pansy Creek helicopter logging sale*[1/]*- Mt. Hood National Forest*

Species	Gross volume	Net volume	Soundness	Proportion of total
	- - -Cubic feet per acre- - -		- - -Percent- - -	
Douglas-fir	1,564.8	1,026.1	65.6	91.3
Hemlock	44.7	41.5	92.8	2.6
Cedar	0	0	0	0
Pines	0	0	0	0
Other softwoods	104.5	45.2	43.2	6.1
Hardwoods	0	0	0	0
Total	1,714.0	1,112.8	64.9	100.0

[1/] Includes all dead and down material averaging at least 3.0 inches in diameter (inside bark) and 4.0 feet long, at least 10 percent sound, and yardable.

Table 10--*Average gross and net volumes of usable logging residue by soundness and species, Study Unit* 1, *Pansy Creek helicopter logging sale*[1/]*--Mt. Hood National Forest*

Percent soundness and species	Gross volume	Net volume	Soundness	Proportion of total
	- - -Cubic feet per acre- - -		- - -Percent- - -	
75+ percent sound:				
Douglas-fir	198.9	192.5	96.8	16.6
Hemlock	497.5	491.2	98.7	41.6
Cedar	0	0	0	0
Pines	0	0	0	0
Other softwoods	498.3	485.7	97.5	41.7
Hardwoods	.8	.8	100.0	.1
Total	1,195.5	1,170.2	97.9	100.0
50+ percent sound:				
Douglas-fir	282.6	243.4	86.1	16.0
Hemlock	740.4	626.8	84.7	42.0
Cedar	0	0	0	0
Pines	0	0	0	0
Other softwoods	740.0	632.3	85.4	42.0
Hardwoods	.8	.8	100.0	0
Total	1,763.8	1,503.3	85.2	100.0
30+ percent sound:				
Douglas-fir	343.6	262.1	76.3	16.3
Hemlock	826.6	658.6	79.7	39.1
Cedar	0	0	0	0
Pines	0	0	0	0
Other softwoods	940.9	705.5	75.0	44.6
Hardwoods	.8	.8	100.0	0
Total	2,111.9	1,626.9	77.0	100.0
10+ percent sound:				
Douglas-fir	418.2	276.6	66.1	16.1
Hemlock	924.7	672.9	72.8	35.6
Cedar	0	0	0	0
Pines	0	0	0	0
Other softwoods	1,254.6	744.0	59.3	48.3
Hardwoods	.8	.8	100.0	0
Total	2,598.3	1,694.3	65.2	100.0

[1/] Includes all down material averaging at least 3.0 inches in diameter (inside bark) and 4.0 feet long, and yardable.

Table 11--*Average gross and net volumes of usable logging residue by soundness and species, Study Unit 2, Pansy Creek helicopter logging sale*[1]*--Mt. Hood National Forest*

Percent soundness and species	Gross volume	Net volume	Soundness	Proportion of total
	- - -Cubic feet per acre- - -		- - -Percent- - -	
75+ percent sound:				
Douglas-fir	776.8	724.2	93.2	34.1
Hemlock	274.5	271.9	99.0	12.1
Cedar	0	0	0	0
Pines	12.2	12.2	100.0	.5
Other softwoods	1,213.3	1,186.5	97.8	53.3
Hardwoods	1.3	1.3	100.0	.1
Total	2,278.1	2,196.1	96.4	[2]100.1
50+ percent sound:				
Douglas-fir	1,037.2	887.0	85.5	38.5
Hemlock	293.4	281.4	95.9	10.9
Cedar	0	0	0	0
Pines	12.2	12.2	100.0	.5
Other softwoods	1,346.6	1,266.4	94.0	50.0
Hardwoods	1.3	1.3	100.0	0
Total	2,690.6	2,448.2	91.0	[2]99.9
30+ percent sound:				
Douglas-fir	1,144.6	923.0	80.6	39.4
Hemlock	293.4	281.4	95.9	10.1
Cedar	0	0	0	0
Pines	12.2	12.2	100.0	.4
Other softwoods	1,451.4	1,300.3	89.6	50.0
Hardwoods	1.3	1.3	100.0	0
Total	2,903.0	2,518.1	86.7	[2]99.9
10+ percent sound:				
Douglas-fir	1,204.8	930.4	77.2	38.4
Hemlock	296.4	281.4	94.9	9.4
Cedar	0	0	0	0
Pines	12.2	12.2	100.0	.4
Other softwoods	1,624.8	1,321.1	81.3	51.8
Hardwoods	1.3	1.3	100.0	0
Total	3,139.5	2,546.3	81.1	100.0

[1] Includes all down material averaging at least 3.0 inches in diameter (inside bark) and 4.0 feet long, and yardable.

[2] Total does not equal 100 because of rounding.

Table 12--*Average gross and net volumes of usable logging residue by soundness and species, Study Unit 3, Pansy Creek helicopter logging sale[1]--Mt. Hood National Forest*

Percent soundness and species	Gross volume	Net volume	Soundness	Proportion of total
	- - -Cubic feet per acre- - -		- - -Percent- - -	
75+ percent sound:				
Douglas-fir	1,398.7	1,364.6	97.6	50.5
Hemlock	748.0	744.8	99.6	27.0
Cedar	0	0	0	0
Pines	0	0	0	0
Other softwoods	620.7	587.0	94.6	22.4
Hardwoods	0	0	0	0
Total	2,767.4	2,696.4	97.4	[2]99.9
50+ percent sound:				
Douglas-fir	1,773.3	1,579.0	89.0	53.4
Hemlock	819.7	786.0	95.9	24.7
Cedar	0	0	0	0
Pines	0	0	0	0
Other softwoods	724.7	648.1	89.4	21.8
Hardwoods	0	0	0	0
Total	3,317.6	3,013.2	90.8	[2]99.9
30+ percent sound:				
Douglas-fir	1,961.5	1,648.9	84.1	54.5
Hemlock	856.4	800.7	93.5	23.8
Cedar	0	0	0	0
Pines	0	0	0	0
Other softwoods	778.7	666.4	85.6	21.7
Hardwoods	0	0	0	0
Total	3,596.7	3,116.0	86.6	100.0
10+ percent sound:				
Douglas-fir	2,139.2	1,676.7	78.4	54.6
Hemlock	862.4	801.6	92.9	22.0
Cedar	0	0	0	0
Pines	0	0	0	0
Other softwoods	914.4	682.7	74.7	23.3
Hardwoods	0	0	0	0
Total	3,916.0	3,161.0	80.7	[2]99.9

[1] Includes all down material averaging at least 3.0 inches in diameter (inside bark) and 4.0 feet long, and yardable.

[2] Total does not equal 100 because of rounding.

About 49 percent, or 2,598 cubic feet per acre (coefficient of variation of 65.8 percent), of the residue remaining after harvesting on unit 1 had utilization potential according to the study specifications. For unit 2, 67 percent, or 3,140 cubic feet per acre (coefficient of variation of 41.1 percent), met these specifications. On unit 3, 69 percent, or 3,916 cubic feet per acre (coefficient of variation of 40.8 percent), could have been used. The average gross and net volumes of usable logging residue remaining on the site are shown for each unit by soundness and by diameter and length classes in tables 13-15. Volumes of usable and unusable logging residue by two soundness classes (10 and 50 percent) are presented in figure 1. A summary of residue volumes for each unit is presented in table 2.

The utilization potential of the residues (both natural and logging) was reduced considerably as the direct result of the harvesting activities. Many pieces were broken and shattered when trees were felled and yarded. The large increase in slab volume after logging in the three units (table 3) indicates considerable shattering occurred during the harvesting operations. Yarding of YUM also contributed to the increase in slab volume. In unit 1 nearly 23 percent of the logging residue volume was in the form of slabs. In units 2 and 3 slabs accounted for 7 and 4 percent, respectively. The highly defective condition of the timber in unit 1 (table 1) probably contributed heavily to the generation of slabs in that unit. Only 1 to 3 percent of the slabs on the study units were considered usable.

We can assume that most of the YUM either met or exceeded the minimum specifications for utilization. For unit 1 the gross volume of YUM was 2,433 cubic feet per acre. When combined with the gross volume of usable residue left on the ground (2,598 cubic feet per acre, see table 13), a total of 5,031 cubic feet per acre of potentially usable residue results (table 2). This is comparable to 6,387 cubic feet per acre of merchantable logs removed from unit 1 during the helicopter logging operation and represents nearly 65 percent of the total residue volume (7,788 cubic feet per acre) generated on the unit (5,355 cubic feet per acre left on the ground, see table 3, plus 2,433 cubic feet per acre of YUM, see table 2).

Though the volumes of YUM removed from units 2 and 3 were not recorded, results from unit 1 suggest that a large part of the usable residues generated on each of the study units was removed as YUM. If this is the case, the recorded usable residues remaining on units 2 and 3 (3,140 and 3,916 cubic feet per acre, respectively, see tables 14 and 15) represent only a portion of the total usable residues available from each of the study units. For unit 1, about 48 percent of the total usable residues was removed as YUM. If we assume that the potential volume of YUM from unit 2 and 3 would be in the same proportions as that removed from unit 1, then the YUM from unit 2 would be 2,941 cubic feet per acre and from unit 3, 3,667 cubic feet per acre. When these amounts are combined with the appropriate volumes of usable residue left on each site, the total usable residues generated would be 6,081 cubic feet per acre on unit 2 and 7,583 cubic feet per acre on unit 3 (table 2). These volumes represent approximately 80 percent of all residues generated on each site, i.e., the residue volume remaining on the ground (table 3) plus the calculated YUM.

Table 13--Average gross and net volumes of usable logging residue by soundness and by diameter and length classes, Study Unit 1, Pansy Creek helicopter logging sale[1]--Mt. Hood National Forest

Percent soundness and diameter class (inches)	Volume of all classes		Length class (feet)							
			4.0-7.9		8.0-13.9		14.0-20.9		21.0+	
	Gross	Net	Gross	Net	Gross	Net	Gross	Net	Gross	Net
	Cubic feet per acre									
75+ percent sound:										
3.0 - 4.4	202.3	200.0	118.0	116.2	56.3	55.8	19.2	19.2	8.8	8.8
4.5 - 7.4	257.1	254.6	68.8	67.8	63.1	62.1	51.3	51.2	73.9	73.6
7.5 - 10.4	205.2	203.0	26.2	25.3	37.4	37.1	48.7	48.1	92.9	92.5
10.5 - 13.4	194.7	191.3	21.4	20.2	37.3	36.4	51.8	51.6	84.2	83.2
13.5 - 16.4	97.3	92.9	0	0	42.0	39.5	28.6	27.5	26.7	25.9
16.5 - 19.4	49.6	47.8	12.9	12.3	5.4	5.4	12.2	11.0	19.0	19.0
19.5 - 22.4	24.2	21.2	7.5	6.0	16.7	15.2	0	0	0	0
22.5 - 25.4	21.7	21.7	0	0	0	0	10.9	10.9	10.9	10.9
25.5 - 28.4	79.5	76.9	14.8	14.8	25.5	25.5	13.7	13.7	25.5	22.9
28.5 - 31.4	31.7	28.5	15.9	14.3	0	0	0	0	15.9	14.3
31.5 - 34.4	0	0	0	0	0	0	0	0	0	0
34.5+	31.7	31.7	0	0	0	0	0	0	31.7	31.7
Slabs	.6	.6	.2	.2	.4	.4	0	0	0	0
Total	1,195.5	1,170.2	285.8	277.1	284.0	277.3	236.4	233.2	389.3	382.7
50+ percent sound:										
3.0 - 4.4	214.5	207.1	128.8	122.5	57.4	56.5	19.5	19.4	8.8	8.8
4.5 - 7.4	273.0	264.4	75.5	71.9	68.3	65.4	54.7	53.3	74.4	73.9
7.5 - 10.4	213.5	208.7	29.3	27.4	41.0	39.6	50.2	49.2	92.9	92.5
10.5 - 13.4	217.4	204.3	24.6	21.8	37.3	36.4	51.8	51.6	103.7	94.6
13.5 - 16.4	127.5	111.8	0	0	54.7	48.4	33.5	29.9	39.4	33.5
16.5 - 19.4	66.6	58.0	12.9	12.3	10.9	8.7	12.2	11.0	30.6	26.0
19.5 - 22.4	96.0	65.7	15.1	11.3	40.8	30.6	25.0	14.8	15.1	9.0
22.5 - 25.4	52.5	40.2	0	0	10.0	6.0	10.9	10.9	31.7	23.4
25.5 - 28.4	93.2	85.2	14.8	14.8	25.5	25.5	13.7	13.7	39.2	31.2
28.5 - 31.4	163.0	104.1	15.9	14.3	15.9	7.9	48.7	27.6	82.6	54.3
31.5 - 34.4	21.8	13.1	0	0	0	0	0	0	21.8	13.1
34.5+	224.4	140.0	0	0	0	0	27.2	16.3	197.1	123.7
Slabs	.6	.6	.2	.2	.4	.4	0	0	0	0
Total	1,763.8	1,503.3	317.0	296.4	362.1	325.3	347.4	297.7	737.2	584.0
30+ percent sound:										
3.0 - 4.4	216.1	207.7	130.0	122.9	57.8	56.7	19.5	19.4	8.8	8.8
4.5 - 7.4	281.2	267.1	79.6	73.3	71.5	66.4	55.7	53.6	74.4	73.9
7.5 - 10.4	222.4	212.0	32.4	28.6	46.8	41.7	50.2	49.2	92.9	92.5
10.5 - 13.4	240.1	211.9	32.3	24.3	46.4	39.7	51.8	51.6	109.6	96.4
13.5 - 16.4	149.4	119.6	8.5	2.9	63.2	51.4	33.5	29.9	44.2	35.5
16.5 - 19.4	96.5	67.6	31.9	18.6	10.9	8.7	17.7	12.6	36.0	27.7
19.5 - 22.4	111.0	71.0	15.1	11.3	48.4	33.6	25.0	14.8	22.6	11.3
22.5 - 25.4	128.6	68.4	0	0	20.8	9.2	10.9	10.9	96.9	48.3
25.5 - 28.4	106.0	90.3	14.8	14.8	25.5	25.5	13.7	13.7	52.0	36.3
28.5 - 31.4	178.9	108.9	15.9	14.3	15.9	7.9	48.7	27.6	98.5	59.1
31.5 - 34.4	21.8	13.1	0	0	0	0	0	0	21.8	13.1
34.5+	358.1	188.2	0	0	0	0	50.3	25.6	307.8	162.7
Slabs	1.9	1.1	.2	.2	1.7	.9	0	0	0	0
Total	2,111.9	1,626.9	360.7	311.2	408.9	341.6	376.9	308.8	965.4	665.3
10+ percent sound:										
3.0 - 4.4	218.8	208.2	131.9	123.2	58.3	56.8	19.8	19.4	8.8	8.8
4.5 - 7.4	289.9	268.1	82.6	73.6	74.5	66.8	58.0	53.8	74.9	73.9
7.5 - 10.4	242.0	214.6	37.0	29.2	55.4	42.8	50.2	49.2	99.4	93.4
10.5 - 13.4	266.5	214.8	41.4	25.5	48.7	39.9	58.6	52.3	117.7	97.2
13.5 - 16.4	201.0	126.1	22.4	4.8	70.6	52.1	55.9	32.5	52.1	36.7
16.5 - 19.4	163.8	76.1	38.7	19.3	21.8	10.3	43.5	15.2	59.8	31.3
19.5 - 22.4	177.6	80.2	15.1	11.3	57.5	35.4	40.1	17.1	65.0	16.4
22.5 - 25.4	150.3	71.6	10.9	1.1	20.8	9.2	10.9	10.9	107.8	50.4
25.5 - 28.4	162.0	101.5	14.8	14.8	25.5	25.5	13.7	13.7	108.0	47.5
28.5 - 31.4	246.7	113.9	15.9	14.3	31.7	9.5	48.7	27.6	150.5	62.5
31.5 - 34.4	42.3	17.2	0	0	0	0	0	0	42.3	17.2
34.5+	428.8	199.7	0	0	0	0	77.5	28.3	351.3	171.4
Slabs	8.5	2.4	6.8	1.5	1.7	.9	0	0	0	0
Total	2,598.3	1,694.3	417.4	318.5	466.5	349.3	476.8	320.0	1,237.6	706.6

[1] Includes all down material averaging at least 3.0 inches in diameter (inside bark) and 4.0 feet long, and yardable.

Table 14--Average gross and net volumes of usable logging residue by soundness and by diameter and length classes, Study Unit 2, Pansy Creek helicopter logging sale[1]--Mt. Hood National Forest

Percent soundness and diameter class (inches)	Volume of all classes		Length class (feet)							
			4.0-7.9		8.0-13.9		14.0-20.9		21.0+	
	Gross	Net	Gross	Net	Gross	Net	Gross	Net	Gross	Net
	-Cubic feet per acre-									
75+ percent sound:										
3.0 - 4.4	241.6	239.5	126.3	124.6	60.1	59.9	28.4	28.2	26.9	26.8
4.5 - 7.4	514.4	505.9	80.6	77.9	125.6	123.1	130.9	129.1	177.3	175.8
7.5 - 10.4	449.4	443.9	100.7	99.1	86.0	85.4	70.7	69.5	192.1	189.9
10.5 - 13.4	309.6	299.4	47.3	46.7	87.8	87.1	37.2	36.6	137.3	128.9
13.5 - 16.4	186.0	175.1	45.7	45.7	49.8	44.0	48.4	46.6	42.1	38.8
16.5 - 19.4	180.0	170.6	30.3	30.3	45.4	42.4	72.3	69.3	32.0	28.6
19.5 - 22.4	140.4	132.5	78.6	74.8	18.7	18.7	22.6	22.6	20.6	16.5
22.5 - 25.4	105.4	100.0	29.2	29.2	0	0	49.4	49.4	26.9	21.5
25.5 - 28.4	34.0	34.0	0	0	34.0	34.0	0	0	0	0
28.5 - 31.4	0	0	0	0	0	0	0	0	0	0
31.5 - 34.4	53.9	43.1	0	0	0	0	53.9	43.1	0	0
34.5+	57.1	45.7	57.1	45.7	0	0	0	0	0	0
Slabs	6.2	6.2	6.2	6.2	0	0	0	0	0	0
Total	2,278.1	2,196.1	602.0	580.3	507.3	494.6	513.7	494.4	655.0	626.7
50+ percent sound:										
3.0 - 4.4	242.9	240.4	127.1	125.2	60.5	60.1	28.4	28.2	26.9	26.8
4.5 - 7.4	522.9	511.3	85.2	80.5	125.6	123.1	134.9	131.9	177.3	175.8
7.5 - 10.4	472.3	456.7	105.4	101.9	92.7	88.8	75.3	72.3	198.8	193.7
10.5 - 13.4	381.5	340.6	58.6	53.5	109.2	99.4	50.6	44.7	163.1	143.0
13.5 - 16.4	310.8	254.0	66.7	59.4	81.4	60.9	57.6	53.0	105.1	80.8
16.5 - 19.4	228.8	200.1	30.3	30.3	60.6	50.0	72.3	69.3	65.6	50.5
19.5 - 22.4	220.8	180.8	97.2	87.9	18.7	18.7	22.6	22.6	82.4	51.7
22.5 - 25.4	159.2	135.2	58.3	49.6	0	0	49.4	49.4	51.5	36.3
25.5 - 28.4	34.0	34.0	0	0	34.0	34.0	0	0	0	0
28.5 - 31.4	0	0	0	0	0	0	0	0	0	0
31.5 - 34.4	53.9	43.1	0	0	0	0	53.9	43.1	0	0
34.5+	57.1	45.7	57.1	45.7	0	0	0	0	0	0
Slabs	6.2	6.2	6.2	6.2	0	0	0	0	0	0
Total	2,690.6	2,448.2	692.2	640.3	582.6	534.9	545.0	514.5	870.8	758.6
30+ percent sound:										
3.0 - 4.4	244.5	240.9	128.0	125.4	61.3	60.4	28.4	28.2	26.9	26.8
4.5 - 7.4	538.3	516.5	90.8	82.4	131.8	125.4	136.1	132.2	179.6	176.5
7.5 - 10.4	475.3	457.9	105.4	101.9	95.7	90.0	75.3	72.3	198.8	193.7
10.5 - 13.4	416.4	353.2	64.2	55.2	117.1	102.6	50.6	44.7	184.5	150.8
13.5 - 16.4	341.0	264.0	66.7	59.4	102.4	68.1	57.6	53.0	114.3	83.6
16.5 - 19.4	228.8	200.1	30.3	30.3	60.6	50.0	72.3	69.3	65.6	50.5
19.5 - 22.4	243.4	189.8	119.8	96.9	18.7	18.7	22.6	22.6	82.4	51.7
22.5 - 25.4	159.2	135.2	58.3	49.6	0	0	49.4	49.4	51.5	36.3
25.5 - 28.4	99.5	53.7	0	0	34.0	34.0	0	0	65.5	19.7
28.5 - 31.4	39.2	11.8	0	0	0	0	0	0	39.2	11.8
31.5 - 34.4	53.9	43.1	0	0	0	0	53.9	43.1	0	0
34.5+	57.1	45.7	57.1	45.7	0	0	0	0	0	0
Slabs	6.2	6.2	6.2	6.2	0	0	0	0	0	0
Total	2,903.0	2,518.1	726.9	653.1	621.6	549.0	546.1	514.8	1,008.4	801.2
10+ percent sound:										
3.0 - 4.4	247.9	241.2	129.1	125.6	63.5	60.6	28.4	28.2	26.9	26.8
4.5 - 7.4	550.2	518.3	93.1	82.6	131.8	125.4	141.7	133.0	183.5	177.2
7.5 - 10.4	510.0	463.0	117.6	103.5	104.7	91.7	85.1	73.7	202.6	194.0
10.5 - 13.4	435.6	355.9	64.2	55.2	125.0	104.1	56.3	45.2	190.1	151.3
13.5 - 16.4	432.9	276.1	66.7	59.4	161.4	76.9	80.0	56.3	124.8	83.6
16.5 - 19.4	242.3	200.1	30.3	30.3	60.6	50.0	85.8	69.3	65.6	50.5
19.5 - 22.4	280.7	193.6	138.5	98.8	18.7	18.7	22.6	22.6	101.0	53.5
22.5 - 25.4	183.9	137.7	83.0	52.0	0	0	49.4	49.4	51.5	36.3
25.5 - 28.4	99.5	53.7	0	0	34.0	34.0	0	0	65.5	19.7
28.5 - 31.4	39.2	11.8	0	0	0	0	0	0	39.2	11.8
31.5 - 34.4	53.9	43.1	0	0	0	0	53.9	43.1	0	0
34.5+	57.1	45.7	57.1	45.7	0	0	0	0	0	0
Slabs	6.2	6.2	6.2	6.2	0	0	0	0	0	0
Total	3,139.5	2,546.3	785.9	659.4	699.6	561.4	603.1	520.8	1,050.9	840.8

[1] Includes all down material averaging at least 3.0 inches in diameter (inside bark) and 4.0 feet long, and yardable.

Table 15--Average gross and net volumes of usable logging residue by soundness and by diameter and length classes, Study Unit 3, Pansy Creek helicopter logging sale[1/]--Mt. Hood National Forest

Percent soundness and diameter class (inches)	Volume of all classes		Length class (feet)							
			4.0-7.9		8.0-13.9		14.0-20.9		21.0+	
	Gross	Net	Gross	Net	Gross	Net	Gross	Net	Gross	Net
	- - -

The piece count of usable residues per acre (excluding YUM) increased nearly tenfold or more after harvesting. Unit 1 had the largest increase with a piece count 13 times greater per acre than that recorded prior to logging. Most of the increase occurred in the small diameter classes of residue. The number of pieces of usable residue per acre is summarized by soundness and by diameter and length classes for each unit before (tables 16-18) and after (table 19-21) the logging operation.

Specifications for yarding unutilized material (see table 1) influenced the distribution of usable residue remaining on the three logging units. There was less volume and fewer pieces of usable residue 12 to 19 inches in diameter on unit 1 (tables 13 and 19) than on units 2 and 3 (tables 14-15 and 20-21). Minimum specifications for YUM on unit 1 included residues in this size range; these were excluded as YUM in units 2 and 3. Because YUM yarding removed the larger pieces of unutilized material from the logging sites, the volume of usable residue remaining was predominantly in pieces not meeting YUM specifications.

Logging residues that were at least 50 percent sound, 8 inches and greater in diameter, and at least 8 feet long averaged 1,163 cubic feet per acre on unit 1, 1,445 cubic feet per acre on unit 2, and 1,886 cubic feet per acre on unit 3 (tables 13-15 and figure 1). These volumes comprise 45 to 48 percent of the usable residues on the study units and probably meet or exceed pulp or utility log specifications. Piece counts corresponding to these volumes are 52 per acre on unit 1, 96 on unit 2, and 142 on unit 3 (tables 19-21). These counts represent, respectively, 6, 9, and 12 percent of the usable pieces of residue on an average acre of each unit. Not included in these estimates is the YUM material removed during the logging operation which meets these specifications.

More than 66 percent of the gross volume of usable residue on unit 1 was from felled trees. On unit 2 this class of residue was nearly 75 percent of the gross volume and on unit 3, 74 percent. Of these amounts, about 56 percent was bucked from longer pieces on unit 1, 60 percent on unit 2, and 65 percent on unit 3. For the previously down residue remaining on the logged units, 11 percent had been bucked from longer pieces on unit 1, 25 percent on unit 2, and 26 percent on unit 3. The volumes of usable logging residue on each logging unit by soundness and material handling class are presented in tables 22-24.

For the three units combined, about 50 percent of the usable residue volume was recorded as having been bucked from larger pieces (i.e., felled and bucked plus down and bucked classes, see tables 22-24). With an alternative bucking procedure, some of this material could have been easily removed from the logging sites. Such a procedure would minimize the amount of tree bole residue left on the area by limiting long butting and bucking out of submerchantable or defective segments and broken log ends. This material would then be yarded intact with the merchantable logs or with the YUM material.

Table 16--*Average number of pieces per acre of usable prelogging residue by diameter and length classes, Study Unit 1, Pansy Creek helicopter logging sale*[1/]*--Mt. Hood National Forest*

Diameter class (inches)	Number of pieces all classes	Length class (feet)			
		4.0-7.9	8.0-13.9	14.0-20.9	21.0+
3.0 - 4.4	21.0	13.0	6.0	1.0	1.0
4.5 - 7.4	7.0	3.0	2.0	1.0	0
7.5 - 10.4	6.0	1.0	2.0	1.0	2.0
10.5 - 13.4	5.0	2.0	2.0	0	1.0
13.5 - 16.4	4.0	0	2.0	1.0	2.0
16.5 - 19.4	2.0	0	1.0	0	1.0
19.5 - 22.4	2.0	1.0	0	0	1.0
22.5 - 25.4	4.0	1.0	1.0	1.0	2.0
25.5 - 28.4	3.0	0	0	1.0	1.0
28.5 - 31.4	2.0	0	0	0	1.0
31.5 - 34.4	0	0	0	0	0
34.5+	2.0	0	0	0	2.0
Slabs	1.0	1.0	0	0	0
Total	61.0	21.0	18.0	7.0	15.0

[1/] Includes all dead and down material averaging at least 3.0 inches in diameter (inside bark) and 4.0 feet long, at least 10 percent sound, and yardable.

Table 17--*Average number of pieces per acre of usable prelogging residue by diameter and length classes, Study Unit 1, Pansy Creek helicopter logging sale*[1/]*--Mt. Hood National Forest*

Diameter class (inches)	Number of pieces all classes	Length class (feet)			
		4.0-7.9	8.0-13.9	14.0-20.9	21.0+
3.0 - 4.4	16.0	11.0	3.0	1.0	1.0
4.5 - 7.4	17.0	3.0	8.0	2.0	4.0
7.5 - 10.4	24.0	2.0	7.0	6.0	9.0
10.5 - 13.4	11.0	2.0	2.0	2.0	5.0
13.5 - 16.4	8.0	0	1.0	1.0	6.0
16.5 - 19.4	4.0	0	1.0	1.0	2.0
19.5 - 22.4	5.0	2.0	0	1.0	3.0
22.5 - 25.4	1.0	0	0	1.0	0
25.5 - 28.4	4.0	0	2.0	1.0	1.0
28.5 - 31.4	3.0	0	0	0	3.0
31.5 - 34.4	0	0	0	0	0
34.5+	2.0	0	1.0	0	1.0
Slabs	1.0	0	1.0	0	0
Total	94.0	19.0	26.0	13.0	37.0

[1/] Includes all dead and down material averaging at least 3.0 inches in diameter (inside bark) and 4.0 feet long, at least 10 percent sound, and yardable.

Table 18--*Average number of pieces per acre of usable prelogging residue by diameter and length classes, Study Unit 3, Pansy Creek helicopter logging sale*[1]*--Mt. Hood National Forest*

Diameter class (inches)	Number of pieces all classes	Length class (feet)			
		4.0-7.9	8.0-13.9	14.0-20.9	21.0+
3.0 - 4.4	5.0	0	2.0	2.0	1.0
4.5 - 7.4	15.0	6.0	1.0	5.0	3.0
7.5 - 10.4	44.0	11.0	11.0	10.0	13.0
10.5 - 13.4	24.0	6.0	7.0	5.0	6.0
13.5 - 16.4	26.0	8.0	6.0	4.0	8.0
16.5 - 19.4	9.0	0	2.0	2.0	5.0
19.5 - 22.4	7.0	0	2.0	1.0	3.0
22.5 - 25.4	0	0	0	0	0
25.5 - 28.4	0	0	0	0	0
28.5 - 31.4	0	0	0	0	0
31.5 - 34.4	0	0	0	0	0
34.5+	0	0	0	0	0
Slabs	0	0	0	0	0
Total	129.0	31.0	30.0	27.0	41.0

[1] Includes all dead and down material averaging at least 3.0 inches in diameter (inside bark) and 4.0 feet long, at least 10 percent sound, and yardable.

Table 19--Average number of pieces per acre of usable logging residue by soundness and by diameter and length classes, Study Unit 1, Pansy Creek helicopter logging sale[1/] - Mt. Hood National Forest

Percent soundness and diameter class (inches)	Number of pieces all classes	Length class (feet)			
		4.0-7.9	8.0-13.9	14.0-20.9	21.0+
75+ percent sound:					
3.0 - 4.4	489.0	383.0	86.0	15.0	5.0
4.5 - 7.4	146.0	80.0	35.0	17.0	14.0
7.5 - 10.4	36.0	13.0	9.0	7.0	7.0
10.5 - 13.4	18.0	5.0	5.0	4.0	4.0
13.5 - 16.4	6.0	0	3.0	2.0	1.0
16.5 - 19.4	1.0	1.0	0	0	0
19.5 - 22.4	2.0	1.0	1.0	0	0
22.5 - 25.4	0	0	0	0	0
22.5 - 28.4	1.0	0	1.0	0	0
28.5 - 31.4	1.0	1.0	0	0	0
31.5 - 34.4	0	0	0	0	0
34.5+	0	0	0	0	0
Slabs	1.0	1.0	0	0	0
Total	701.0	485.0	140.0	45.0	31.0
50+ percent sound:					
3.0 - 4.4	525.0	417.0	88.0	15.0	5.0
4.5 - 7.4	157.0	88.0	37.0	18.0	14.0
7.5 - 10.4	38.0	14.0	10.0	7.0	7.0
10.5 - 13.4	20.0	6.0	5.0	4.0	5.0
13.5 - 16.4	7.0	0	4.0	2.0	1.0
16.5 - 19.4	3.0	1.0	1.0	0	1.0
19.5 - 22.4	5.0	2.0	2.0	1.0	0
22.5 - 25.4	0	0	0	0	0
25.5 - 28.4	1.0	0	1.0	0	0
28.5 - 31.4	2.0	1.0	0	1.0	0
31.5 - 34.4	0	0	0	0	0
34.5+	0	0	0	0	0
Slabs	1.0	1.0	0	0	0
Total	759.0	530.0	148.0	48.0	33.0
30+ percent sound:					
3.0 - 4.4	529.0	420.0	89.0	15.0	5.0
4.5 - 7.4	163.0	92.0	39.0	18.0	14.0
7.5 - 10.4	41.0	16.0	11.0	7.0	7.0
10.5 - 13.4	22.0	7.0	6.0	4.0	5.0
13.5 - 16.4	9.0	1.0	5.0	2.0	1.0
16.5 - 19.4	6.0	3.0	1.0	1.0	1.0
19.5 - 22.4	5.0	2.0	2.0	1.0	0
22.5 - 25.4	2.0	0	1.0	0	1.0
25.5 - 28.4	1.0	0	1.0	0	0
28.5 - 31.4	3.0	1.0	0	1.0	1.0
31.5 - 34.4	0	0	0	0	0
34.5+	1.0	0	0	0	1.0
Slabs	2.0	1.0	1.0	0	0
Total	784.0	543.0	156.0	49.0	36.0
10+ percent sound:					
3.0 - 4.4	537.0	426.0	90.0	16.0	5.0
4.5 - 7.4	169.0	95.0	41.0	19.0	14.0
7.5 - 10.4	45.0	18.0	13.0	7.0	7.0
10.5 - 13.4	25.0	9.0	6.0	5.0	5.0
13.5 - 16.4	13.0	3.0	6.0	3.0	1.0
16.5 - 19.4	8.0	4.0	2.0	1.0	1.0
19.5 - 22.4	6.0	2.0	2.0	1.0	1.0
22.5 - 25.4	3.0	1.0	1.0	0	1.0
25.5 - 28.4	2.0	0	1.0	0	1.0
28.5 - 31.4	4.0	1.0	1.0	1.0	1.0
31.5 - 34.4	0	0	0	0	0
34.5+	2.0	0	0	1.0	1.0
Slabs	2.0	1.0	1.0	0	0
Total	816.0	560.0	164.0	54.0	38.0

[1/] Includes all down material averaging at least 3.0 inches in diameter (inside bark) and 4.0 feet long, and yardable.

Table 20--Average number of pieces per acre of usable logging residue by soundness and by diameter and length classes, Study Unit 2, Pansy Creek helicopter logging sale[1/] - Mt. Hood National Forest

Percent soundness and diameter class (inches)	Number of pieces all classes	Length class (feet)			
		4.0-7.9	8.0-13.9	14.0-20.9	21.0+
75+ percent sound:					
3.0 - 4.4	530.0	407.0	87.0	23.0	13.0
4.5 - 7.4	235.0	93.0	65.0	41.0	36.0
7.5 - 10.4	88.0	44.0	20.0	10.0	14.0
10.5 - 13.4	34.0	15.0	11.0	3.0	5.0
13.5 - 16.4	17.0	9.0	4.0	3.0	1.0
16.5 - 19.4	8.0	3.0	2.0	2.0	1.0
19.5 - 22.4	9.0	7.0	1.0	1.0	0
22.5 - 25.4	3.0	2.0	0	1.0	0
25.5 - 28.4	1.0	0	1.0	0	0
28.5 - 31.4	0	0	0	0	0
31.5 - 34.4	1.0	0	0	1.0	0
34.5+	2.0	2.0	0	0	0
Slabs	2.0	2.0	0	0	0
Total	930.0	584.0	191.0	85.0	70.0
50+ percent sound:					
3.0 - 4.4	536.0	412.0	88.0	23.0	13.0
4.5 - 7.4	241.0	98.0	65.0	42.0	36.0
7.5 - 10.4	92.0	45.0	22.0	10.0	15.0
10.5 - 13.4	41.0	17.0	14.0	4.0	6.0
13.5 - 16.4	24.0	12.0	7.0	3.0	2.0
16.5 - 19.4	9.0	3.0	3.0	2.0	1.0
19.5 - 22.4	12.0	9.0	1.0	1.0	1.0
22.5 - 25.4	5.0	3.0	0	1.0	1.0
25.5 - 28.4	1.0	0	1.0	0	0
28.5 - 31.4	0	0	0	0	0
31.5 - 34.4	1.0	0	0	1.0	0
34.5+	2.0	2.0	0	0	0
Slabs	2.0	2.0	0	0	0
Total	966.0	603.0	201.0	87.0	75.0
30+ percent sound:					
3.0 - 4.4	540.0	415.0	89.0	23.0	13.0
4.5 - 7.4	249.0	103.0	68.0	42.0	36.0
7.5 - 10.4	93.0	45.0	23.0	10.0	15.0
10.5 - 13.4	46.0	20.0	15.0	4.0	7.0
13.5 - 16.4	27.0	12.0	9.0	3.0	3.0
16.5 - 19.4	9.0	3.0	3.0	2.0	1.0
19.5 - 22.4	13.0	10.0	1.0	1.0	1.0
22.5 - 25.4	5.0	3.0	0	1.0	1.0
25.5 - 28.4	1.0	0	1.0	0	0
28.5 - 31.4	0	0	0	0	0
31.5 - 34.4	1.0	0	0	1.0	0
34.5+	2.0	2.0	0	0	0
Slabs	2.0	2.0	0	0	0
Total	988.0	615.0	209.0	87.0	77.0
10+ percent sound:					
3.0 - 4.4	546.0	418.0	92.0	23.0	13.0
4.5 - 7.4	254.0	105.0	68.0	44.0	37.0
7.5 - 10.4	102.0	50.0	25.0	12.0	15.0
10.5 - 13.4	47.0	20.0	15.0	5.0	7.0
13.5 - 16.4	33.0	12.0	14.0	4.0	3.0
16.5 - 19.4	10.0	3.0	3.0	3.0	1.0
19.5 - 22.4	15.0	12.0	1.0	1.0	1.0
22.5 - 25.4	7.0	5.0	0	1.0	1.0
25.5 - 28.4	1.0	0	1.0	0	0
28.5 - 31.4	0	0	0	0	0
31.5 - 34.4	1.0	0	0	1.0	0
34.5+	2.0	2.0	0	0	0
Slabs	2.0	2.0	0	0	0
Total	1,020.0	629.0	219.0	94.0	78.0

[1/] Includes all down material averaging at least 3.0 inches in diameter (inside bark) and 4.0 feet long, and yardable.

Table 21--Average number of pieces per acre of usable logging residue by soundness and by diameter and length classes, Study Unit 3, Pansy Creek helicopter logging sale[1]--Mt. Hood National Forest

Percent soundness and diameter class (inches)	Number of pieces all classes	Length class (feet)			
		4.0-7.9	8.0-13.9	14.0-20.9	21.0+
75+ percent sound:					
3.0 - 4.4	501.0	415.0	73.0	8.0	5.0
4.5 - 7.4	315.0	242.0	38.0	19.0	16.0
7.5 - 10.4	167.0	102.0	30.0	17.0	18.0
10.5 - 13.4	61.0	27.0	21.0	7.0	6.0
13.5 - 16.4	32.0	18.0	7.0	5.0	2.0
16.5 - 19.4	11.0	6.0	3.0	1.0	1.0
19.5 - 22.4	3.0	2.0	1.0	0	0
22.5 - 25.4	5.0	5.0	0	0	0
25.5 - 28.4	2.0	1.0	1.0	0	0
28.5 - 31.4	1.0	1.0	0	0	0
31.5 - 34.4	0	0	0	0	0
34.5+	0	0	0	0	0
Slabs	6.0	6.0	0	0	0
Total	1,104.0	825.0	174.0	57.0	48.0
50+ percent sound:					
3.0 - 4.4	510.0	424.0	73.0	8.0	5.0
4.5 - 7.4	321.0	244.0	40.0	20.0	17.0
7.5 - 10.4	177.0	105.0	33.0	19.0	20.0
10.5 - 13.4	67.0	31.0	22.0	7.0	7.0
13.5 - 16.4	40.0	21.0	7.0	8.0	4.0
16.5 - 19.4	15.0	6.0	5.0	2.0	2.0
19.5 - 22.4	5.0	2.0	2.0	1.0	0
22.5 - 25.4	7.0	5.0	1.0	0	1.0
25.5 - 28.4	5.0	4.0	1.0	0	0
28.5 - 31.4	1.0	1.0	0	0	0
31.5 - 34.4	0	0	0	0	0
34.5+	0	0	0	0	0
Slabs	6.0	6.0	0	0	0
Total	1,154.0	849.0	184.0	65.0	56.0
30+ percent sound:					
3.0 - 4.4	510.0	424.0	73.0	8.0	5.0
4.5 - 7.4	323.0	246.0	40.0	20.0	17.0
7.5 - 10.4	181.0	105.0	35.0	20.0	21.0
10.5 - 13.4	71.0	32.0	23.0	8.0	8.0
13.5 - 16.4	43.0	23.0	8.0	8.0	4.0
16.5 - 19.4	22.0	9.0	7.0	3.0	3.0
19.5 - 22.4	6.0	2.0	3.0	1.0	0
22.5 - 25.4	8.0	5.0	1.0	1.0	1.0
25.5 - 28.4	5.0	4.0	1.0	0	0
28.5 - 31.4	1.0	1.0	0	0	0
31.5 - 34.4	0	0	0	0	0
34.5+	0	0	0	0	0
Slabs	6.0	6.0	0	0	0
Total	1,176.0	857.0	191.0	69.0	59.0
10+ percent sound:					
3.0 - 4.4	514.0	427.0	74.0	8.0	5.0
4.5 - 7.4	339.0	258.0	42.0	21.0	18.0
7.5 - 10.4	193.0	112.0	37.0	21.0	23.0
10.5 - 13.4	82.0	35.0	28.0	9.0	10.0
13.5 - 16.4	46.0	24.0	10.0	8.0	4.0
16.5 - 19.4	23.0	9.0	8.0	3.0	3.0
19.5 - 22.4	6.0	2.0	3.0	1.0	0
22.5 - 25.4	8.0	5.0	1.0	1.0	1.0
25.5 - 28.4	6.0	4.0	2.0	0	0
28.5 - 31.4	1.0	1.0	0	0	0
31.5 - 34.4	0	0	0	0	0
34.5+	0	0	0	0	0
Slabs	8.0	8.0	0	0	0
Total	1,226.0	885.0	205.0	72.0	64.0

[1] Includes all down material averaging at least 3.0 inches in diameter (inside bark) and 4.0 feet long, and yardable.

Table 22--*Average gross and net volumes of usable logging residue by soundness and material handling class, Study Unit 1, Pansy Creek helicopter logging sale*[1]*- Mt. Hood National Forest*

Percent soundness and material handling class	Gross volume	Net volume	Soundness	Proportion of total
	- - -Cubic feet per acre- - -		- - -Percent- - -	
75+ percent sound:				
Felled and bucked	548.1	538.9	98.3	45.8
Felled and broken	609.6	600.1	98.4	51.0
Down and bucked	9.8	8.2	84.1	.8
Down and broken	28.0	23.0	82.2	2.3
Total	1,195.5	1,170.2	97.9	[2]99.9
50+ percent sound:				
Felled and bucked	817.4	692.3	84.7	46.3
Felled and broken	724.1	669.3	92.4	41.1
Down and bucked	25.8	19.4	75.3	1.5
Down and broken	196.6	122.4	62.2	11.1
Total	1,763.8	1,503.3	85.2	100.0
30+ percent sound:				
Felled and bucked	937.1	736.3	78.6	44.4
Felled and broken	746.7	677.3	90.7	35.4
Down and bucked	76.0	36.2	47.6	3.6
Down and broken	352.1	177.2	50.3	16.7
Total	2,111.9	1,626.9	77.0	[2]100.1
10+ percent sound:				
Felled and bucked	961.4	736.9	76.7	37.0
Felled and broken	764.9	680.9	89.0	29.4
Down and bucked	99.8	40.5	40.5	3.8
Down and broken	772.2	236.0	30.6	29.7
Total	2,598.3	1,694.3	65.2	[2]99.9

[1] Includes all down material averaging at least 3.0 inches in diameter (inside bark) and 4.0 feet long, and yardable.

[2] Total does not equal 100 because of rounding.

Table 23--*Average gross and net volumes of usable logging residue by soundness and material handling class, Study Unit 2, Pansy Creek helicopter logging sale*[1]*- Mt. Hood National Forest*

Percent soundness and material handling class	Gross volume	Net volume	Soundness	Proportion of total
	- - -Cubic feet per acre- - -		- - -Percent- - -	
75+ percent sound:				
Felled and bucked	1,233.5	1,202.6	97.5	54.1
Felled and broken	819.4	803.5	98.1	36.0
Down and bucked	57.9	48.0	82.9	2.5
Down and broken	167.3	142.1	84.9	7.3
Total	2,278.1	2,196.1	96.4	[2]99.9
50+ percent sound:				
Felled and bucked	1,358.7	1,281.5	94.3	50.5
Felled and broken	838.3	814.6	97.2	31.2
Down and bucked	122.8	89.3	72.8	4.6
Down and broken	370.9	262.9	70.9	13.8
Total	2,690.6	2,448.2	91.0	[2]100.1
30+ percent sound:				
Felled and bucked	1,389.2	1,292.9	93.1	47.9
Felled and broken	918.2	839.5	91.4	31.6
Down and bucked	167.6	102.9	61.4	5.8
Down and broken	428.0	282.8	66.1	14.7
Total	2,903.0	2,518.1	86.7	100.0
10+ percent sound:				
Felled and bucked	1,401.1	1,294.1	92.4	44.6
Felled and broken	943.6	842.0	89.2	30.1
Down and bucked	195.9	107.5	54.9	6.2
Down and broken	598.9	302.8	50.6	19.1
Total	3,139.5	2,546.3	81.1	100.0

[1] Includes all down material averaging at least 3.0 inches in diameter (inside bark) and 4.0 feet long, and yardable.

[2] Total does not equal 100 because of rounding.

Table 24--*Average gross and net volumes of usable logging residue by soundness and material handling class, Study Unit 3, Pansy Creek helicopter logging sale*[1]*- Mt. Hood National Forest*

Percent soundness and material handling class	Gross volume	Net volume	Soundness	Proportion of total
	- - -Cubic feet per acre- - -		- - -Percent- - -	
75+ percent sound:				
Felled and bucked	1,591.8	1,571.9	98.8	57.5
Felled and broken	827.6	821.3	99.2	29.9
Down and bucked	111.6	95.5	85.6	4.0
Down and broken	236.4	207.7	87.9	8.5
Total	2,767.4	2,696.4	97.4	[2]99.9
50+ percent sound:				
Felled and bucked	1,809.2	1,693.4	93.6	54.5
Felled and broken	913.5	869.3	95.2	27.5
Down and bucked	181.8	139.4	76.7	5.5
Down and broken	413.1	311.0	75.3	12.5
Total	3,317.6	3,013.2	90.8	100.0
30+ percent sound:				
Felled and bucked	1,866.6	1,714.7	91.9	51.9
Felled and broken	984.0	896.2	91.1	27.4
Down and bucked	222.9	154.4	69.3	6.2
Down and broken	523.1	350.8	67.1	14.5
Total	3,596.7	3,116.0	86.6	100.0
10+ percent sound:				
Felled and bucked	1,866.6	1,714.7	91.9	47.7
Felled and broken	1,022.3	903.5	88.4	26.1
Down and bucked	261.7	158.7	60.7	6.7
Down and broken	765.5	384.1	50.2	19.5
Total	3,916.0	3,161.0	80.7	100.0

[1] Includes all down material averaging at least 3.0 inches in diameter (inside bark) and 4.0 feet long, and yardable.

[2] Total does not equal 100 because of rounding.

CONCLUDING REMARKS

Since results of the present investigation are based on only a case study of one particular helicopter logging operation, inferences drawn from these results may not necessarily be applicable to other operations logged in the same manner. The information presented, however, can still be used by forest managers in evaluating residue production, its reduction, characteristics, volumes, and potential uses. Some indication of the fuel loading that can be expected from similar harvesting operations is also made available. Furthermore, a basis is provided with which to evaluate the effects of change in utilization either from changes in the market or in contractural requirements such as required yarding of unutilized material (YUM). Results of this study are summarized in table 2.

Our data indicate YUM yarding substantially reduced the coarse residue volumes in the study units. Contractual specifications for yarding unutilized materials influenced the volume and piece-count distribution of the usable residues remaining on the site. Study results tend to suggest YUM yarding was less effective in a partial cut than in a clearcut.

Even with YUM yarding, we found a substantial volume of residues (usable and unusable) (table 2) still remaining on the logging sites. Our results suggest that these residues, because of their size and character, will continue to be a problem regardless of whether or not the logging operation calls for the yarding of unutilized materials.

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CONVERSION FACTORS

1 inch = 2.54 centimeters
1 foot = 0.304 8 meter
1 acre = 0.404 686 2 hectare
1 cubic foot acre = 0.069 972 5 cubic meter/hectare

1 pound (lb) = 0.453 6 kilogram
1 ton = 2,000 lbs = 907.2 kilograms
1 bone-dry unit of chips (BDU) = 2,400 pounds

Specific density (oven-dry weight/green volume)
(Hartman [1976] table E-1)
Coast Douglas-fir = 28.0 pounds per cubic foot
Western hemlock = 26.2 pounds per cubic foot

1 cubic foot Douglas-fir = 0.011 666 6 BDU chips
1 cubic foot western hemlock = 0.010 916 6 BDU chips

1 cubic foot Douglas-fir = 249,000 Btu per cubic foot
(Hartman [1976] table G-1)
1 cubic foot western hemlock = 204,000 Btu per cubic foot

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